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Effect of Resin and Thickness on Tensile Properties of Laminated Composites

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Abstract: *The use of composites in the aerospace industry has increased dramatically. Primary benefits that composite components can offer are reduced weight and assembly simplification. The performance advantages associated with reducing the weight of aircraft structural elements has been the major impetus for military aviation composites development. Although commercial carriers have increasingly been concerned with fuel economy, the potential for reduced production and maintenance costs has proven to be a major factor in the push towards composites.The results of tensile tests are used in selecting materials for engineering applications and are frequently included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared.The present investigation was undertaken to determine the influence of Resin & Thickness of Laminates on glass fiber Epoxy, graphite fiber Epoxy and Carbon fiber Epoxy laminates with glass fiber Polyester, graphite fiber polyester and carbon fiber polyester resin under Tensile loads.*

Keywords*: Laminate, Tensile Strength, Resin, Stiffness, Strength*

I. Introduction

The application of laminated composites are increased in all sorts of engineering applications especially in aerospace ,sports, transportation marine and in all sorts of engineering applications due to high specific strength and stiffness. Fiber reinforced composite materials are selected for weight critical applications and these materials have good rating as per the fatigue failure is concerned. Present work is aimed to analyze the mechanical behavior of an each laminate under tensile condition. The basic concepts of composites material along with details of earlier works are explained by author at reference. A brief review is given of techniques which have been employed in attempts to determine the mechanical properties of composite materials under tensile &impact loading by J. Harding and L.M. Welsh, [1]. B. Gommers et.al [2] determined the mechanical properties of composite materials by tensile tests. Mauricio et al [3] predicted the elastic behavior of hybrid plain weave fabric composites with different materials and undulations in the warp and weft directions by formulating a 3D analytical micromechanical model. Ala Tabiei and Ivelin Ivanov [4] developed a micromechanical material model of woven fabric composite materials with failure. The elastic properties and notch sensitivity of untreated woven jute and jute–glass fabric reinforced polyester hybrid composites was investigated analytically and experimentally by Sabeel Ahmed [5].Barbero et al [6] determined the mechanical properties of plain weave fabrics by developing accurate finite element models. The effects of skew angle, aspect ratio and boundary condition on large deflection static behavior of thin isotropic skew plates under uniformly distributed load was investigated by Debabrata Das [7]. Varatharajan [7] has conducted extensive tensile, flexure and interlaminar tests on glass/polypropylene and glass/polyester composites.From the above literature, it is very evident that the effect of thickness and influence of resin system onthe tensile properties of composite materials is very less &scanty. Hence, in this work it is proposed to experimentally investigate the influence of specimen thickness with different resin system on tensile properties of laminated composite specimens.

II. Experimental Procedure

Materials: Bi woven Carbon fiber, Glass fiber & Graphite fiber are used as reinforcement materials in the form of bi directional, Epoxy & Polyester resins are used as Matrix materials for the laminate preparations with the hardeners HY140 & MEPK respectively for epoxy resin and Polyester resin respectively.

Resin used	MATERIAL
EPOXY RESIN	GLASS FIBER
	GRAPHITE FIBER
	CARBON FIBER
POLYESTER RESIN	GLASS FIBER
	GRAPHITE FIBER
	CARBON FIBER

Testing:

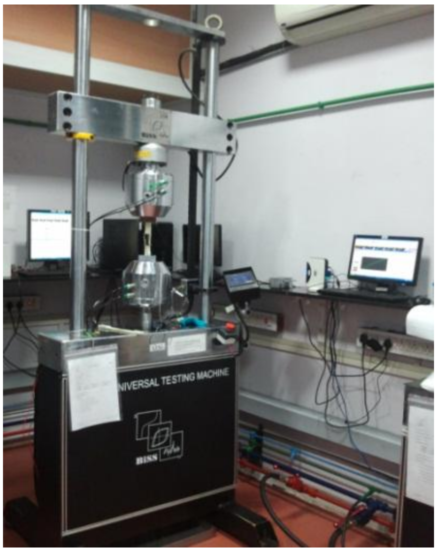


Fig.: Specimen mounted on UTM

The composite laminates were subjected to various loads and computer controlled UTM. The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the completed fracture of the specimen occurred has been accepted as breakage load.

III. Specimen preparation

Two types of Resins Epoxy resin and Polyester Resins are used to prepare the Glass fiber, Graphite and Carbon fiber laminates as shown in the table 1 & 2.

Case 1: Epoxy resin as matrix material

Composite laminates were fabricatedat room temperature (24 -26ºC) in a clean and net environment. Composite laminates were fabricated by hand lay-up process, proper care was taken during the preparation of laminates to maintain the uniform thickness and to prevent the voids. The first layer of Bi-woven glass fiber cloth (ranging from 0.25 mm to 0.35 mm) is laid and resin is spread uniformly over the cloth by means of brush. The second layer of the cloth is laid and resin is spread uniformly over the cloth by means of brush. After second layer, to enhance wetting and impregnation, a teethed steel roller is used to roll over the fabric before applying resin. Also resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (2 mm thickness) and 16 layers (4 mm thickness) are placed. No external pressure is applied while casting and curing because uncured matrix material can squeeze out under high pressure. This results in surface waviness (non-uniformed thickness) in the model material. The casting is cured at oven temperature of about 100º C up to 2 hrs & finally removed from the mold to get a fine finished composite plate. The below picture shows the clear view of the fabrication process. This process is repeated to prepare the Graphite and carbon based epoxy resin laminates.

Preparation of test specimens

After the cure process, the test specimens are cut from the sheet to the following size as per ASTM standards (ASTM D-790) by using diamond impregnated wheel, cooled by running water. All the specimens are finished by abrading the edges on a fine carborundum paper.

Case 2: Polyester resin as matrix material

The laminates were fabricated by placing one layer of bi woven fabric over the other. Polyester resin was applied as a matrix material in between each layer, tools were used to distribute resin uniformly as explained earlier and a teethed steel roller is used to roll over the fabric before applying resin. Also, resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (for 2mm thickness) and 16 layers (4mm thickness) are placed without applying any kind of external pressure. The surfaces of the laminates were covered to prevent lay up from external disturbance. After proper curing about 2 days at room temperature the specimens were cut in required sizes per ASTM (ASTM D-790) standards. In all, 24 specimens were prepared as indicated in Table 1 & Table 2.

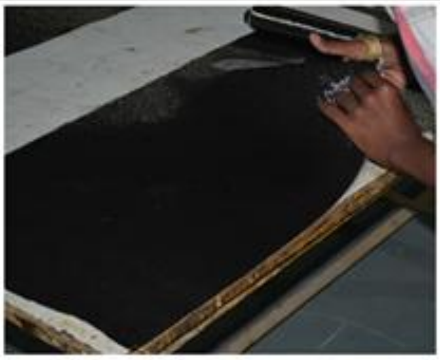


Fig – 1 Cutting of Graphite Cloth

Fig – 2 Hand Lay up

Fig – 3 Applicatoin of Resin

Fig – 4 Stacking sequence

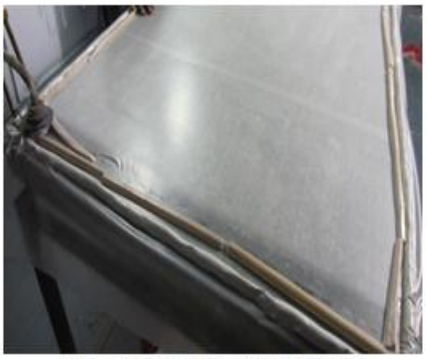


Fig – 5 Vacuum Bagging Technique

Table 1- Designation of glass, carbon & Graphite specimens reinforced with epoxy resin

SI	Specimen Designation	Description
1	CATE/02/01	CARBON FIBER /2 mm THICKNESS/SAMPLE 01
2	CATE/02/02	CARBON FIBER/2 mm THICKNESS/SAMPLE 02
3	CATE/04/01	CARBON FIBER/4 mm THICKNESS/SAMPLE 01
4	CATE/04/02	CARBON FIBER/4 mm THICKNESS/SAMPLE 02
5	GRTE/02/01	GRAPHITE FIBER/2mm THICKNESS/SAMPLE 01
6	GRTE/02/02	GRAPHITE FIBER/2mm THICKNESS/SAMPLE 02
7	GRTE/04/01	GRAPHITE FIBER/4mm THICKNESS/SAMPLE 01
8	GRTE/04/02	GRAPHITE FIBER/4mm THICKNESS/SAMPLE 02
9	GLTE/02/01	GLASS FIBER/2 mm THICKNESS/SAMPLE 01
10	GLTE/02/02	GLASS FIBER/2 mm THICKNESS/SAMPLE 02
11	GLTE/04/01	GLASS FIBER/4 mm THICKNESS/SAMPLE 01
12	GLTE/04/02	GLASS FIBER/4 mm THICKNESS/SAMPLE 02

Table 2- Designation of glass, carbon & Graphite specimens reinforced with Polyester resin.

SI	Specimen Designation	Description
1	CATP/02/01	CARBON FIBER /2 mm THICKNESS/SAMPLE 01
2	CATP/02/02	CARBON FIBER/2 mm THICKNESS/SAMPLE 02
3	CATP/04/01	CARBON FIBER/4 mm THICKNESS/SAMPLE 01
4	CATP/04/02	CARBON FIBER/4 mm THICKNESS/SAMPLE 02
5	GRTP/02/01	GRAPHITE FIBER/2mm THICKNESS/SAMPLE 01
6	GRTP/02/02	GRAPHITE FIBER/2mm THICKNESS/SAMPLE 02
7	GRTP/04/01	GRAPHITE FIBER/4mm THICKNESS/SAMPLE 01
8	GRTP/04/02	GRAPHITE FIBER/4mm THICKNESS/SAMPLE 02
9	GLTP/02/01	GLASS FIBER/2 mm THICKNESS/SAMPLE 01
10	GLTP/02/02	GLASS FIBER/2 mm THICKNESS/SAMPLE 02
11	GLTP/04/01	GLASS FIBER/4 mm THICKNESS/SAMPLE 01
12	GLTP/04/02	GLASS FIBER/4 mm THICKNESS/SAMPLE 02

Table 3- Designation and Measured Dimensions of Glass, Graphite and carbon specimens reinforced with Epoxy Resin.

Specimen Designation (EPOXY RESIN)	length (mm)	Width (mm)	Thickness (mm)
GLTE/02/01	250.2	25.1	2.2
GLTE/02/02	250.5	24.8	2.1
GLTE/04/01	249.3	25.2	4.2
GLTE/04/02	250.1	25.3	4.1
GRTE/02/01	250.1	24.9	1.9
GRTE/02/02	250.1	25.1	2.1
GRTE/04/01	250.3	24.8	4.1
GRTE/04/02	250.1	25.3	4.2
CATE/02/01	250.3	25.2	2.1
CATE/02/02	249.9	24.9	2.1
CATE/04/01	248.9	24.7	4.2
CATE/04/02	250.4	25.2	4.3

Table 4- Designation and Measured Dimensions of Glass, Graphite and carbon specimens reinforced with Polyester Resin.

Specimen Designation (polyester resin)	length (mm)	Width (mm)	Thickness (mm)
GLTP/02/01	250	25.2	2.1
GLTP/02/02	250.2	24.9	2.1
GLTP/04/01	249.9	25.1	4.3
GLTP/04/02	251.1	25.2	4.2
GRTP/02/01	248.1	25.1	2.1
GRTP/02/02	250.1	25.1	2.2
GRTP/04/01	250.9	25.3	4.1
GRTP/04/02	250.9	25.3	4.1
CATP/02/01	250.3	25.1	2.2
CATP/02/02	250.3	24.9	2.1
CATP/04/01	249.6	25.1	4.2
CATP/04/02	251	25.4	4.1

IV. Results

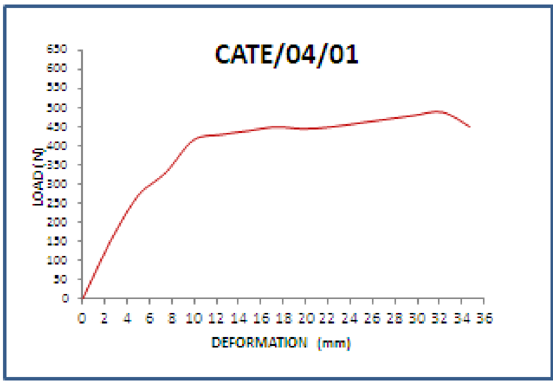
Table-5: Tensile Properties Glass, Carbon and Graphite composites with 2mm & 4mm thickness Reinforced with Epoxy Resin.

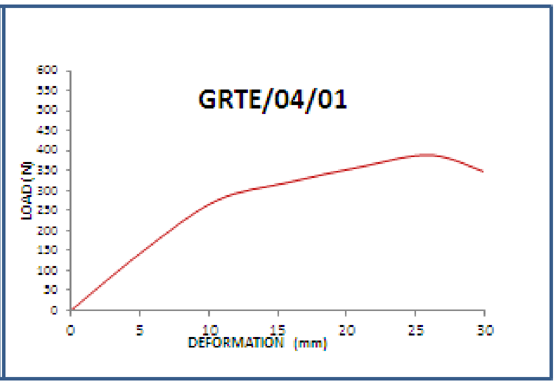
Specimen (Epoxy resin)	Peak Load, kN	Yield Strength MPa	Ultimate Strength, MPa	Max Deformation, mm	Stiffness N/mm
CATE/02/01	30.52	321.94	512.03	18.16	1680.62
CATE/02/02	35.21	302.02	545.06	22.15	1589.62
CATE/04/01	86.15	415.12	489.12	32.24	2672.15
CATE/04/02	89.56	433.32	504.51	33.68	2659.14
GRTE/02/01	22.45	294.03	412.14	12.11	1853.84
GRTE/02/02	19.22	304.21	416.15	14.66	1311.05
GRTE/04/01	52.22	391.56	389.15	26.33	1983.29
GRTE/04/02	49.78	389.18	387.43	22.08	2254.53
GFTE/02/01	19.64	332.68	377.24	8.3	2366.26
GFTE/02/02	20.32	316.7	398.23	8.78	2314.5
GFTE/04/01	33.64	328.62	408.83	13.1	2567.94
GFTE/04/02	30.44	297.14	366.49	11.4	2670.17

Table-6: Tensile Properties Glass, Carbon and Graphite composites with 2mm & 4mm thickness Reinforced with Polyester Resin.

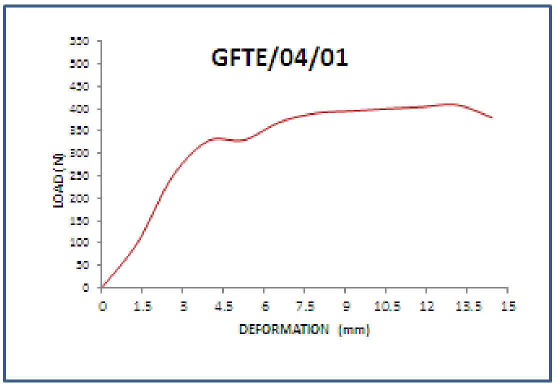
Specimen (polyester resin)	Peak Load, kN	Yield Strength MPa	Ultimate Strength, MPa	Max Deformation, mm	Stiffness N/mm
GFTP/02/01	14.77	218.71	299.13	7.7	1918.18
GFTP/02/02	12.97	200.15	302.16	6.9	1879.71
GFTP/04/01	38.68	150.91	245.6	19.68	1965.45
GFTP/04/02	36.85	154.81	255.9	21.85	1686.5
GRTP/02/01	19.88	264.57	402.33	9.88	2012.15
GRTP/02/02	20.53	288.38	414.12	10.53	1949.67
GRTP/04/01	49.74	303.03	378.19	21.24	2341.81
GRTP/04/02	46.41	389.09	381.12	22.4	2071.88
CATP/02/01	28.67	294.56	498.14	15.35	1867.75
CATP/02/02	30.77	289.94	513.15	18.16	1694.38
CATP/04/01	68.44	395.67	463.18	26.74	2559.46
CATP/04/02	69.15	400.36	455.1	28.13	2458.23

Graphs:

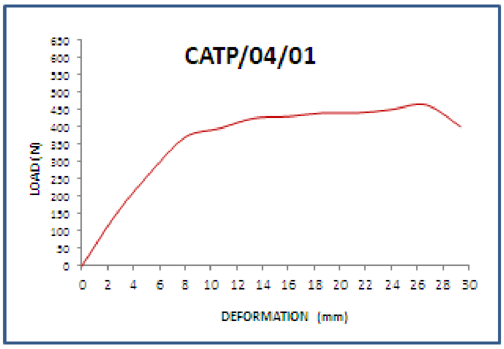


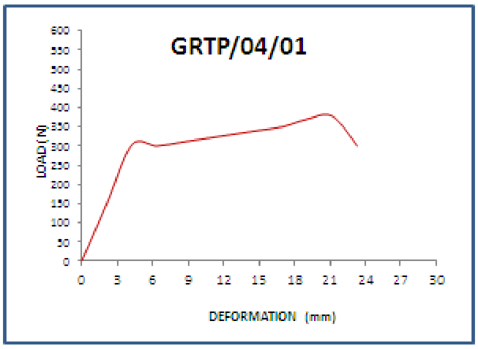


Graph 01: Carbon fiber +Epoxy resin (04mm thickness) Graph 02: Graphite fiber +Epoxy resin (04mm Thickness)



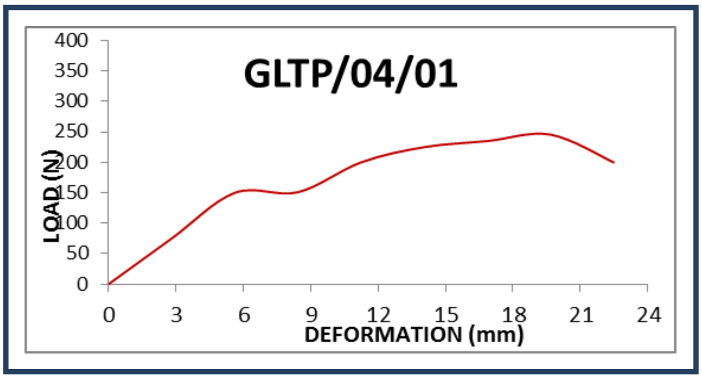
Graph 03: Glass fiber +Epoxy resin (04mm thickness)





Graph 04: Carbon fiber + polyester resin (04mm thickness) Graph 05: Graphite fiber +Polyester resin (04mm thickness)

Graph 06: Glass fiber +polyester resin (04mm thickness)



V. Discussions

The results obtained from experimental work on the Tensile testing of different fibers of with different resin system in laminated composites are illustrated in Table-5 & 6 and the following observations were recorded. The load increases sharply in case of 4mm thick specimen as compared to 2mm laminates as indicated in the table 5 & 6.Increase in thickness of laminates tends to decrease the tensile strength. Load required to fracture the same is completely depends upon the thickness of the specimen and it has been observed 15-30% of load is required to break the specimen completely.The extension of the specimen under the loads completely depends upon the thickness of the specimen. Load at yield point also increase with the thickness of the specimen.The specimen reinforced with epoxy resin tends to show more strength compared to specimen with polyester resin. It is quite evident that elongation decreases with increase in thickness of all types of specimen.

This study is carried out in order to investigate the tensile properties of three types of laminated composites namely Glass fiber, Graphite fiber and Carbon fiber with epoxy and polyester resins as matrix materials. The specimens are subjected to axial load. Tensile test is conducted to establish the strength and modulus of elasticity for the composite laminates. This test had given the basic concept of the effect of thickness and different resin system onto the tensile properties of the laminated composites. The results of experiments show that the tensile properties of the specimens were increased when epoxy resin was used as matrix system.

VI. Conclusions

The main conclusions drawn from the experimental investigation of tensile tests on laminated composite material are as follows:

- In this work, tensile test on two different thicknesses with two different resins of bi-woven glass epoxy, graphite epoxy and carbon epoxy specimenswere compared with glass polyester, graphite polyester and carbon polyester resin tested and results recorded. The influence of specimen thickness and influence of resin on the tensile properties were evaluated and it is found that the increase in thickness increases the tensile properties such as ultimate strength, stiffness along with the resin used.
- Tensile properties of Epoxy Glass, Graphite and Carbon Laminates of 2mm and 4 mm thicknesses with Epoxy Resin and Polyester Resin were successfully conducted and results are recorded.
- The laminated specimens with lesser thickness leads to more ultimate tensile strength
- Specimens sustain greater loads in carbon epoxy as compared to carbon polyester resin.
- Extension is minimum in the case of glass fiber polyester resin as compared to other specimens.
- The effects of specimen thickness & resin on tensile properties were evaluated and it is found that the specimen's reinforced with epoxy resin shows better tensile properties as compared to the specimen reinforced with polyester resin.

Finally, it can be concluded that for same thickness and orientation, carbon fiber reinforced with epoxy resin provides better tensile properties as compared to glass and graphite resin reinforced with both epoxy resin and polyester resin under tensile loading conditions.

VII. Acknowledgments

Authors thankfully acknowledge the Principal and Head of the Department of Mechanical Engineering UVCE, Bangalore for their constant encouragement and support in carrying out this work.

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